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AIR ENFORCEMENT BRANCH,  
U.S. EPA, REGION 5

October 18, 2005

*Via UPS*

Chief, Environmental Enforcement Section  
Environmental and Natural Resources Division  
United States Department of Justice  
Box 7611 Ben Franklin Station  
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*Via E-Mail*

Mr. Cary Secrest  
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United States Environmental Protection  
Agency  
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1200 Pennsylvania Avenue, N.W.  
Washington, D.C. 20460

Mr. Kevin L. Vuilleumier, Environmental  
Engineer  
Air Enforcement and Compliance Assurance  
Branch  
U.S. Environmental Protection Agency  
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Air Enforcement and Compliance Assurance  
United States Environmental Protection  
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Mr. Myron Eng  
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U.S. Environmental Protection Agency  
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E-Mail: [Eng.myron@epamail.epa.gov](mailto:Eng.myron@epamail.epa.gov)

Re: DOJ No. 90-11-2-06089, U.S. v. Buckeye Egg Farm, L.P., et al., United  
States District Court, Northern District of Ohio, Western Division, Civil  
Action No. 3:03CV7681

Dear Ladies and Gentlemen:

As required in the Consent Decree in United States v. Buckeye Egg Farm, L.P., et al., Ohio Fresh Eggs, LLC is submitting a report concerning the Preliminary Test of an Electrostatic Space Charging System in a High Rise Layer Barn. Please promptly advise whether EPA deems these results acceptable so that Ohio Fresh Eggs may continue Silsoe testing of this PM control measure.

October 18, 2005

Page 2

Should you need any additional information, please contact me.

Very truly yours,

KEATING MUETHING & KLEKAMP PLL

By:   
Brian M. Babb

Enclosure

cc: Mr. Donald C. Hershey  
Dr. Albert J. Heber

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AIR ENFORCEMENT BRANCH  
U.S. EPA REGION 5

CERTIFICATION

I certify under penalty of law that this document and any attachments to it were prepared under my direction or supervision in accordance with a system designed to ensure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing and willful submission of a materially false statement.

OHIO FRESH EGGS, LLC

  
Donald C. Hershey, Manager

1232938.1

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## BIOGRAPHICAL RESUME

### Albert J. Heber, Ph.D., P.E., Professor

Purdue University, 225 S. University St., Agricultural and Biological Engineering  
West Lafayette, IN 47907-1146

Phone: (765) 494-1214 Fax: (765) 496-1115 E-mail: [heber@purdue.edu](mailto:heber@purdue.edu)

URL: [www.AgAirQuality.com](http://www.AgAirQuality.com)

## EDUCATION

Ph.D., Engineering, University of Nebraska-Lincoln, 5/84

M.S., Agricultural Engineering, South Dakota State University, 12/79

B.S., Agricultural Engineering, South Dakota State University, 8/78

## PROFESSIONAL POSITIONS AND EXPERIENCE

- 6/02 *Professor*, Agricultural and Biological Engineering, Purdue University, West Lafayette, IN
- 7/85 *President*, Heber Consulting, LLC, Delphi, IN
- 6/93- 6/02 *Associate Professor*, Agricultural Engineering, Purdue University, West Lafayette, IN
- 8/1/90-  
7/25/91 *Visiting Scientist*, Silsoe Research Institute, Silsoe, UK.
- 6/17-9/15/93
- 9/5/00-3/1/01
- 7/89-6/93 *Associate Professor*, Agricultural Engg., Kansas State University, Manhattan, KS
- 5/84-6/89 *Assistant Professor*, Agricultural Engg, Kansas State University, Manhattan, KS
- 6/81-5/84 *Research Engineer II*, Agricultural Engineering, Univ. Nebraska, Lincoln, Nebraska
- 1/80-6/81 *Instructor*, Agricultural Engineering, South Dakota State Univ., Brookings, SD
- 7/78-12/79 *Graduate Research Assistant*, Agricultural Engineering, SDSU, Brookings, SD

## HONORARY AND PROFESSIONAL SOCIETIES

Alpha Epsilon Honorary Member, 1986

Air and Waste Management Association, 2002-present

American Association of Aerosol Science, 1987-1988

American Society of Agricultural Engineers, 1980-present

American Society of Engineering Education, 1985-1987

American Society of Heating, Refrigeration and Air Conditioning Engineers, 1992-present

Gamma Sigma Delta, Honor Society of Agriculture, 1978

Phi Kappa Phi, Honor Society, 1978

Sigma Xi, Scientific Research Society, 1980

The Aerosol Society, 1990-1996,

Tau Beta Pi, Engineering Honor Society, 1977

## PROFESSIONAL RECOGNITION



Selected by Livestock Industries as Research Leader of National Air Emissions Monitoring Project.

Article featured in Resource magazine, 2003.

Transactions of ASAE Article Honorable Mentions, 1993, 1995

Member of the Year, ASAE Kansas Section, 1992

Advisor of the Year, Agricultural Engineering Department, KSU, 1992

Blue Ribbon in ASAE Educational Aids Competition for MWPS - 33, 1990

Outstanding Reviewer, ASAE Structures and Environment Division, 1987

Journal paper selected for feature article in Agricultural Engineering magazine, 1986

New Engineering Educator Delegate to National ASEE meeting, 1985

Ralston-Purina Scholarship, 1977, 3M Engineering Scholarship, 1976

## AREAS OF EXPERTISE

Dr. Heber's primary research is currently on the assessment and mitigation of dust, odor and gas emissions from agricultural facilities and waste storage and treatment facilities. His work is addressing a critical need in the nation, as environmental concerns about modern livestock production units increase and as regulations become more stringent. Other areas of expertise are livestock building and equipment, building ventilation design, and air systems.

Dr. Heber has 20 years experience in livestock facility research, education, and consulting with emphasis on air quality. He directs Purdue's Agricultural Air Quality Laboratory, which utilizes state-of-the-art stack samplers, olfactometry, gas chromatography, FTIR spectrometry, continuous analyzers for  $\text{NH}_3$ ,  $\text{H}_2\text{S}$ ,  $\text{CO}_2$ ,  $\text{CH}_4$ , NMHC, TSP,  $\text{PM}_{10}$ ,  $\text{PM}_{2.5}$ , and meteorological instruments. He developed a unique mobile air quality lab in 1994 to monitor gas emissions, and to establish science-based emission factors for livestock. This led to industrial funding in 1996 of the most comprehensive building air emission tests ever conducted, involving eight swine finishing buildings. This was followed by a 1999 pork industry grant to test 35 manure additives and a federal grant in 2000 to develop a standard for livestock building  $\text{PM}_{10}$  and ammonia ( $\text{NH}_3$ ) emission measurements. In 2001, he spearheaded federally-funded, large-scale, comprehensive emission measurement campaigns in collaboration with seven other universities and major swine and poultry producers and served as technical director and quality assurance manager. Since 2000, Dr. Heber has published 14 journal articles, given 29 invited papers and lectures, and provided scientific expertise and information on livestock emission factors, emission measurements, and emission controls at livestock facilities to state and federal agencies and the livestock industry. He presented the opening keynote address to the Enviro04 Odour Conference in Sydney, Australia in March, 2004.

Other research has involved development of a science-based setback model for U.S. pork production facilities, testing of odor measurement protocols, pathogen emission and dispersion from swine houses, and odor emission from swine farrowing, nursery and finishing buildings and laying houses, outdoor manure treatment facilities, and industrial composting operations. He is coauthor of 4 USDA white papers on  $\text{NH}_3$ , odor and PM emissions, and siting of livestock facilities. Dr. Heber has received \$18.2M in gifts and awards with direct responsibility for over \$4.3M.

## PROFESSIONAL ACTIVITIES

### *National Committees*

USDA-NRCS Air Quality Group, 2003-04 (Develop protocol for nationwide emission monitoring).

National Research Council Report on Air Emissions from Livestock Facilities, 2002

Reviewer, Interim Report; Review Coordinator, Final Report

American Society of Agricultural Engineers

SE-02 Steering Committee of Structures and Environment Division, Member, 1998-00.

SE-06 Program Committee of Structures and Environment Division, Member, 1998-00.

SE-30 Structures and Environment Division Environment Group Chair, 1998-00.

SE-305 Environmental Air Quality Committee, 1986-present; Nominating Subcommittee Chair, 1992; Structures Subcommittee Chair, 1993-95

SE-302 Environment of Animal Structures Committee Member, 1989-present



Sec., 1993-94, Vice-Chair, '94-95, Chair, '95-96, Past-Chair, '96-97; Assoc. Editor, '93-94  
American Society of Heating, Refrigeration and Air Conditioning Engineers

TC 2.2 Plant & Animal Environment Committee, 1993-04; Res. Subcommittee Chair, '93-03

### ***Regional and State Committees***

Indiana Department of Environmental Management CAFO Air Quality Committee, 2002-present.

NCR 189: Air Quality Issues Associated with Animal Facilities, '96-02, Sec., '97-98, Chair, '98-99.

International Conference on Air Pollution from Agricultural Operations, Conference Chairman  
and Chair of Program Subcommittee, 1995-96

Mid-Central Conference of American Society of Agricultural Engineers

Chairman, 1989-1990, Program Committee Member, 1986-1988, and Chairman, 1988-1989

Kansas Committee on the Relation of Electricity to Agriculture

Chair, 1988-89, Sec.-Treas., 1985-89; Exec. Committee, 1985-90; Ad-Hoc Member, 1991-93.

Kansas Section of American Society of Agricultural Engineers

Nominating Committee: Member, 1985; Chairman, 1986, Awards Committee Member, 1992-93

NCR-9 Midwest Plan Service

Agricultural Experiment Station Rep., 1985-93; Executive Committee Member, 1988-90

NCS-3 Integrated Health Management for Confined Swine; Task Force Member, 1986-1987

## **FACULTY RESPONSIBILITIES**

### ***Purdue University***

Purdue Cooperative Extension Specialists Assoc., Dept Rep., 1993-97, Prof. Improvement

Committee, 1993-94, Chair 1994-95; Pres.-Elect, 1996-97; Pres., 1997-98; Past-Pres., 1998-99.

School of Agriculture Grievance Committee, 1995-1996; Acting Chair, Jan., 1996

School of Agriculture Extension Education Committee, 1995-97

School of Agriculture Agenda and Policy Committee, 1995-98

School of Engineering Grade Appeals Committee, Chair, 1996-98

University Grade Appeals Committee, 1998-present, Chair, 2002-2003

### ***Department***

Graduate Committee, 1994-1996

Awards Committee, 1995-present, Chair, 2002-present

Extension Committee, 1993-present

Family Day Committee Chair, 1996-present

### ***Kansas State University***

Research Assoc. of the KS Technology Enterprise Corp. Adv. Man. Inst. 1988-93

College of Agriculture Honors Advisory Committee, 1988-1990

Agricultural Experiment Station Conference Committee, 1992-93

Graduate Faculty Member, 1985-93

Engineering Academic Reinstatement Committee, 1984-1990

Kansas Electric Utilities Research Program Advisory Committee, 1988-93

### ***Department***

Structures and Environment Technical Committee Chairman, 1989-93

Graduate Committee, 1988-93

Honors Committee, 1988-89

Room Scheduling Committee Chair, 1988-89

Scholarship Committee, 1988-89

Course and Curriculum, 1987-93

Facilities and Space Committee, 1985-89

Engineering Open House, Co-advisor, 1985-86; Advisor, 1987-89

## TEACHING

### *Student Advising*

*Kansas State University:* Agricultural Mechanization Undergraduate Students, 1984-90; Agricultural Engineering Undergraduate Students, 1986-93; Major Professor: 2 -M.S. Agricultural Mechanization Students, 1985-93; 6 -M.S. Agricultural Engineering Students, 1986-93; 1-Ph.D. Engineering Student, 1988-93; Advisor to 2-Postdoctoral Researchers, 1989, 1991-92

*Purdue University:* Major Professor to: 1 M.S. Agricultural Systems Management Student; 1 M.S. Extension Education Student; 2 M.S. Agricultural Engineering Students; 3 Ph.D. Agricultural Engineering Student; 5 Postdoctoral researchers; 3 sabbatical visitors

### *Undergraduate Courses*

#### *South Dakota State University*

Ag Eng 444 "Electric Power and Processing," 1981

Mech Ag 342 "Electricity for the Farm and Home," 1980-81

Mech Ag 443 "Processing of Agricultural Products," 1981

#### *University of Nebraska*

Ag Eng 460 "Agricultural Instrumentation and Controls" (50%), 1983

#### *Kansas State University*

Ag Eng 500 "Physical Properties of Biological Materials", 1990

Ag Eng 510 "Environmental Design of Agric. Buildings," 1984-89,91-92

Ag Eng 566 "Design of Agricultural Structures," 1985-93

AgTechM 511 "Agricultural Building Systems," 1985-88, 90(labs),92-93

#### *Purdue University*

ABE 590 "Air Biofiltration", 2003 (4 graduate students)

ASM 570 "Agricultural Structures", 1995-04 (one month on building environment)

AGEN 556 "Food Plant Design", 1994, 1995, 1996 (one week of ventilation)

### *Graduate Course*

#### *Kansas State University*

Ag Eng 811 "Particle Technology", 1988-89,92

## INVENTION DISCLOSURES

Ni, J.-Q. and A.J. Heber. 2001. Method and Apparatus for Air Pollution Control, Comprising Multi-Level Trays Containing Down Flowing Algae Culture. PRF P-00090. Invention Disclosed to the Purdue University Research Foundation.

Banks, M.K. and A.J. Heber. 2003. Simultaneous Treatment of Multi-Media Waste Streams Using Biological Trickle Filters. Invention Disclosed to the Purdue University Research Foundation.

Heber, A.J., L. Vasan, and J.T. Cole. 2003. Dual Conveyor Jet Impingement Oven. Invention Disclosure GTI-1543, Gas Technology Institute, Chicago, IL.

## PATENTS

Heber, A.J. 1995. Conveyor Oven with Improved Air Flow. U.S. Patent No. 5,421,316. Filed Jan. 31, 1994. Assignee: G.S. Blodgett Corporation, Burlington, VT, June 6.

Heber, A.J. 1992. Variable Speed Control of Livestock Ventilation Fans Using Discrete Feedback of Motor Speed. U.S. Patent No. 5,125,571. Filed May 21, 1990. Assignee: Kansas State University Research Foundation, Manhattan, KS, June 30.

## PEER-REVIEWED JOURNAL ARTICLES (total= 39)

1. Miller, G.Y., R.G. Maghirang, G.L. Riskowski, A.J. Heber, M.J. Robert and M.E.T. Muyot. 2004. Influences on air quality and odor from mechanically ventilated swine finishing buildings in Illinois. *J. Food, Agriculture & Environment* 2(2):(in press).



2. Arogo, J., P.W. Westerman, and A.J. Heber. 2003. A review of ammonia emissions from confined swine feeding operations. *Trans. ASAE* 46(3):805-817.
3. Lim, T.-T., A.J. Heber, J.-Q. Ni, A.L. Sutton, and P. Shao. 2003. Odor and gas release from anaerobic treatment lagoons for swine manure. *J. Environmental Quality* 32(2): 406-416.
4. Heber, A.J. 2002. Effects of high oil corn and soybean oil additives on dustiness of ground corn and feed. *Trans. ASAE* 18(5): 1593-1598.
5. Heber, A.J., J.-Q. Ni, and T.-T. Lim. 2002. Odor flux measurements at a facultative swine lagoon stratified by surface aeration. *Applied Engineering in Agriculture* 18(5): 593-602.
6. Heber, A.J., M.J. Peugh, N.J. Zimmerman, and R.L. Linton. 2002. Poultry slaughter plants: ventilation system performance. *ASHRAE Trans.* 108(2): 129-144.
7. Ni, J.-Q., A.J. Heber, C.A. Diehl, T.-T. Lim, R.K. Duggirala, and B.L. Haymore. 2002. Characteristics of hydrogen sulfide concentrations in mechanically ventilated swine buildings. *Canadian Biosystems Engineering* 44(6):11-19.
8. Ni, J.-Q., A.J. Heber, T.-T. Lim, C.A. Diehl, R.K. Duggirala, and B.L. Haymore. 2002. Hydrogen sulfide emission from two large pig finishing buildings with long term high frequency measurements. *J. Agricultural Science* 138(2):227-236.
9. Ni, J.-Q., A.J. Heber, C.A. Diehl, T.-T. Lim, R.K. Duggirala, and B.L. Haymore. 2002. Summertime concentrations and emissions of hydrogen sulfide at a mechanically-ventilated swine finishing building. *Trans. ASAE* 45(1): 193-199.
10. Heber, A.J., J.-Q. Ni, B.L. Haymore, R.K. Duggirala, and K.M. Keener. 2001. Air quality and emission measurement methodology at swine finishing buildings. *Trans. ASAE* 44(6):1765-1778.
11. Lim, T.-T., A.J. Heber, J.-Q. Ni, A.L. Sutton, and D.T. Kelly. 2001. Characteristics and emission rates of odor from swine nursery buildings. *Trans. ASAE* 44(5):1275-1282.
12. Heber, A.J., J.-Q. Ni, T.-T. Lim, C.A. Diehl, A.L. Sutton, R.K. Duggirala, B.L. Haymore, D.T. Kelly, and V.A. Adamchuk. 2000. Effect of a manure additive on ammonia emission from swine finishing buildings. *Trans. ASAE* 43(6):1895-1902.
13. Parbst, K.E., K.M. Keener, A.J. Heber, and J.-Q. Ni. 2000. Comparison between low-end discrete and high-end continuous measurements of air quality in swine buildings. *Applied Engineering in Agriculture* 16(6): 693-699.
14. Ni, J.-Q. A.J. Heber, C.A. Diehl, and T.-T. Lim. 2000. Ammonia, hydrogen sulfide and carbon dioxide release from pig manure in under-floor deep pits. *J. Agric. Engineering Res.* 77(1):53-66.
15. Ni, J.-Q. A.J. Heber, T.-T. Lim, C.A. Diehl, R.K. Duggirala, B.L. Haymore, and A.L. Sutton. 2000. Ammonia emissions from a large mechanically-ventilated swine building during warm weather. *J. Environmental Quality* 29(3):752-758.
16. Lutgring, K.R., R.H. Linton, N.J. Zimmerman, M. Peugh, and A.J. Heber. 1997. Distribution and quantification of bioaerosols in poultry-slaughtering plants. *J. Food Protection* 60(7):804-810.
17. Heber, A.J., C.R. Boon, and M.W. Peugh. 1996. Air patterns and turbulence in an experimental livestock building. *J. Agric. Engineering Res.* 64:209-226.
18. Kaiser, K.J., A.J. Heber, and M.H. Hosni. 1996. New ceiling and wall agricultural ventilation inlets. *Applied Engineering in Agriculture* 12(2):237-242.
19. Heber, A.J. and J. Li. 1995. Predicting variable-speed fan performance from motor and impeller characteristics. Part I - Using complete motor data. *Trans. ASAE* 38(4):1247-1252.
20. Li, J. and A.J. Heber. 1995. Predicting variable-speed fan performance from motor and impeller characteristics. Part II - Using limited motor data. *Trans. ASAE* 38(4):1253-1259.
21. Pickrell J A, Heber A J, Murphy J P, Henry S C, May M M, Nolan D, Gearhart S K, Cederberg B L, Oehme F W, Schoneweis D. 1995. Total respirable dust in swine confinement buildings. The benefit of respiratory protective masks and effect of recirculated air. *Vet Hum Toxicology* 37 (5):430-435.
22. El-Koubysi, A.R., A.J. Heber, and M.M. Morcos. 1994. Harmonics produced by variable-speed fan systems. *Trans. ASAE*, 37(2): 679-685. **(Honorable Mention)**
23. Kaiser, K.J., M.H. Hosni, and A.J. Heber. 1994. Performance of passively automatic ventilation inlets for agricultural buildings. *ASHRAE Trans.* 101(1):1054-1064.



24. Morcos, M.M., J.A. Mowry, and A.J. Heber. 1994. A solid-state speed controller for capacitor motors driving agricultural fans. *IEEE Trans. on Industry Applications*, 30(3), May- June.
25. Li, J., A.J. Heber, and G.L. Johnson. 1993. Variable speed fan performance with single- and three-phase motors. *Trans. ASAE* 36(6):1973-1978.
26. Morcos, M.M., J.A. Mowry, and A.J. Heber. 1993. A new speed controller for induction motors driving agricultural fans. *J. Agricultural Engineering Research* 54(2):159-169.
27. Pickrell, J.A., A.J. Heber, J.P. Murphy, S.C. Henry, M.M. May, D. Nolan, F.W. Oehme, J.R. Gillespie, and D. Schoneweiss. 1992. Characterization of particles, ammonia and endotoxin in swine confinement operations. *Veterinary and Human Toxicology* 35(5):421-428.
28. Heber, A.J. and C.R. Boon. 1992. Air velocity characteristics in an experimental livestock building with nonisothermal jet ventilation. *Trans. of ASHRAE* 99(1):1139-1151
29. Li, J. and A.J. Heber. 1992. Optimizing performance of variable speed fans. *Trans. ASAE* 35(5):1737-1744. **(Honorable Mention)**
30. Heber, A.J., S.E. Cole, and J.P. Murphy. 1991. Facility for testing exhaust ventilation fans. *Applied Engineering in Agriculture* 7(5):599-605.
31. Li, J., A.J. Heber, and G.L. Johnson. 1990. Electrical power harmonics at rural substations and farms. *Trans. ASAE* 33(6):2051-2057.
32. Slocombe, J.W., L.E. Wagner, A.J. Heber, and J.P. Harner. 1990. Test equipment for determining performance of electric motors. *Applied Engineering in Agriculture* 6(1):97-100.
33. Wagner, L.E., A.J. Heber, and J.P. Harner. 1990. PC-based electric motor dynamometer data acquisition program. *Applied Engineering in Agriculture* 6(5):643-646.
34. Heber, A.J. and C.R. Martin. 1988. Effect of additives on aerodynamic segregation of dust from swine feed. *Trans. ASAE* 31(2):558-563.
35. Heber, A.J., M. Stroik, J.L. Nelssen, and D.A. Nichols. 1988. Influence of environmental factors on concentrations and inorganic content of aerial dust in swine finishing units. *Trans. ASAE* 31(3):875-881.
36. Heber, A.J., M. Stroik, J.M. Faubion, and L.H. Willard. 1988. Size distribution and identification of aerial dust particles in swine finishing buildings. *Trans. ASAE* 31(3):882-887.
37. Heber, A.J., T.L. Thompson, and D.D. Schulte. 1986. Development of an on-farm electrical load management system. *Trans. ASAE* 29(1):281-287.
38. Heber, A.J., T.L. Thompson, and D.D. Schulte. 1986. Simulation model for on-farm electrical load management. *Trans. ASAE* 29(5):1405-1412.
39. Heber, A.J., M.A. Hellickson, and L. Verma. 1982. SEI-TES: Solar heating for swine housing. *Trans. ASAE* 25(6):1680-1684.

#### PEER-REVIEWED ABSTRACTS (5 total)

1. Tengman, C.L., R.N. Goodwin, A.K. Gralap-Gonzalez, A.J. Heber, J.-Q. Ni, K.J. Fakhoury and A.L. Sutton. 2002. Odor solutions initiative manure pit additive testing results. *J. Animal Science*, p. 51, Midwest ASAS/ADSA meeting (Abstract).
2. Hankins, S.L., S.A. DeCamp, B.T. Richert, D.B. Anderson, D.J. Ivers, A.J. Heber, and A.L. Sutton. 2001. Odor production in stored manure from ractopamine (RAC) fed pigs. *J. Animal Science* 69:61 (Abstract).
3. Hankins, S.L., A.L. Sutton, J.A. Patterson, B.T. Richert, A.J. Heber, D.T. Kelly, K.B. Kephart, R. Mumma, E. Bogus, and S.D. Carter. 2001. Reduction of odorous compounds in pig manure through dietary fiber manipulation. *J. Animal Science* 78(Suppl. 1):187 (Abstract).
4. Hankins, S.L., A.L. Sutton, J.A. Patterson, O. Adeola, B.T. Richert, A.J. Heber, D.T. Kelly, and K.B. Kephart. 2000. Diet modification to reduce odorous compounds in pig manure. *J. Animal Science* 78(Suppl. 1):187 (Abstract).
5. Sutton, A.L., K.B. Kephart, J.A. Patterson, D.D. Jones, A.J. Heber, D.T. Kelly, R. Mumma, and E. Bogus. 1998. Amino acids and carbohydrates in pig diets to reduce ammonium nitrogen and pH in manure. *J. Animal Science* 76(Suppl.1):173 (Abstract).

#### EXTENSION MATERIALS



- Heber, A.J. and H. Person. 2002. Odor control options for confined feeding. Part 11, Best Environmental Management Practices for Farm Animal Production, Michigan State University, East Lansing, MI 48824
- Sweeten, J.M., L.D. Jacobson, A.J. Heber, D.R. Schmidt, J.C. Lorimor, P.W. Westerman, J.R. Miner, R.H. Zhang, C.M. Williams, and B.W. Auvermann. 2001. Odor Mitigation for Concentrated Animal Feeding Operations: White Paper and Recommendations. National Center for Manure and Animal Waste Management, NC State University, Raleigh, NC. 54 p.
- Arogo, J., P.W. Westerman, A.J. Heber, W.P. Robarge, and J.J. Classen. 2001. Ammonia Produced by Animal Production – White Paper. National Center for Manure and Animal Waste Management, North Carolina State University, Raleigh, NC. 53 p.
- Jacobson, L.D., S.L. Wood, D.R. Schmidt, A.J. Heber, J.R. Bicudo, and R.D. Moon. 2001. Site Selection of Animal Operations using Air Quality Criteria – White Paper. National Center for Manure and Animal Waste Management, North Carolina State University, Raleigh, NC. 38 p.
- Auvermann, B., R. Bottcher, A.J. Heber, D. Meyer, C.B. Parnell, Jr., B. Shaw, and J. Worley. 2001. Particulate Matter Emissions from Animal Feeding Operations – White Paper. National Center for Manure and Animal Waste Management, North Carolina State University, Raleigh, NC. 40 p.
- Heber, A.J., D.D. Jones, and A.L. Sutton. 1999. Methods and practices to reduce odor from swine facilities. AQ-2. Purdue University Cooperative Extension Service, Jan.
- Mechanical ventilating systems, MWPS-32. 1989. Midwest Plan Service, Ames, IA. (Author of chapter on air quality and reviewer for handbook.) 69 p.
- Natural ventilation of livestock buildings, MWPS-33. 1990. Midwest Plan Service, Ames, IA. (Chapter on air quality published in MWPS-32 modified for use here. Also served on writing committee to develop, write and review handbook.) 31 p.
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11. Heber, A.J. 1998. Analysis of Ambient Hydrogen Sulfide Concentrations Near a Hog Production Facility. Final Report to B&S Research, Inc., Mar. 10, 28 p.
12. Heber, A.J., M.W. Peugh, R.H. Linton, N.J. Zimmerman, and K. Lutgring. 1998. The Effect of Processing and Air Flow Parameters on Microbial Aerosol Dispersion in Poultry Plants. Final Report of ASHRAE Research Project 834-RP, Dec. 31, 206 p.
13. Heber, A.J. J. Straslipka, T.-T. Lim, J.-Q. Ni, and R. Trivedi. 1998. Maintaining Finish Quality With Low-to-No VOC Wood Coatings, Final Report, IN Dept. of Env. Management, Dec. 31, 54 p.
14. Heber, A.J., J.-Q. Ni, and A.L. Sutton. 1998. Field Tests of Alliance. Final Report, Monsanto EnviroChem. Sept. 28. 260+ p.
15. Heber, A.J. 1998. Effects of Lagoon Aeration on Odor Emissions from a Swine Grow-Finish Facility. Final Report to Ramco Sales, Inc., Cushing, Oklahoma. Sept. 8, 23 p.
16. Heber, A.J. 1997. Effect of Pegulit and Pegulit+ on Gas and Odor Emissions from Stored Swine Manure. Final Report to ETM International Trading and Recycling, Aug. 19, 7 p.
17. Heber, A.J., J.A. Patterson, L. Dong, B.R. Strobel, A.L. Sutton, and D.D. Jones. 1996. Bioscrubber for Removing Ammonia from Building Exhaust Air." Final Report, IN Pork Producers Assoc, Oct. 21.
18. Heber, A.J., B.R. Strobel, C.C. Wu, A.L. Sutton, J.A. Patterson, and D.D. Jones. 1996. Effects of Management Practices on Air Quality in Swine Farrowing Houses. Final Rep., IN Pork Prod.. Sep. 20.
19. Heber, A.J. and A.R. El-Koubysi. 1993. Computer Automation of Fan Test Laboratory. Final Report to the Advanced Manufacturing Institute, Durland Hall, KSU, Mar. 18.
20. Heber, A.J. and B. Misra. 1993. Selection of Components for Mechanical Ventilation Systems. Final Report to the Kansas Committee on the Relation of Electricity to Agriculture, Agricultural Engineering Department, Kansas State University, Mar. 1.



21. Heber, A.J., J. Li, and J.P. Harner. 1992. FANSYS: A Design Program for Single- and Variable-Speed Fans. Final Report to Osborne Industries, Sept. 30.
22. Morcos, M.M., A.J. Heber, and J.A. Mowry. 1992. Solid-State Speed Controllers For Single-Phase Capacitor Motors. Final Report for Project 2782-4, EPRI TR-100174, Jan. National Rural Electric Corporation Association and Electric Power Research Institute.
23. Heber, A.J., B. Zhang, and J. Li. 1992. Microprocessor-Embedded Controller for Ventilation Fans. Final Report to the Advanced Manufacturing Institute, Durland Hall, KSU, Aug. 20.
24. Pickrell, J.A., A.J. Heber, J.P. Murphy, F.W. Oehme, D. Schoneweis, J.R. Gillespie, and S.C. Henry. 1992. Ammonia, Total and Respirable Dust and Endotoxin in Swine Confinement Buildings. National Pork Producers Council, Research Investment Report.
25. Heber, A.J., A.R.M. El-Koubysi, M.M. Morcos, and J.P. Harner. 1990. Harmonics Produced from Variable Speed Fan Systems. Final Report to Kansas Electric Utility Research Program. Sept. 22.
26. Heber, A.J., J.P. Li, M.M. Morcos, and J.P. Harner. 1990. Design Optimization of Variable Speed Fan Systems. Final Report to Osborne Industries. Dec. 1.
27. Heber, A.J. and T.N. Bisping. 1989. Effect of Pelletized Fat and Soybean Oil on Aerodynamic Dust Segregation of Swine Feed. Final report submitted to Balanced Energy Company. June 26.
28. Heber, A.J., J.P. Murphy, and J.W. Slocombe. 1989. Variable-Speed Control for Direct-Drive Ventilation Fans. Final Report to Osborne Industries, Inc. and the KS Tech. Enterprise Corp. Feb. 17.
29. Heber, A.J., J.P. Murphy, and S.E. Cole. 1988. Advancement of technology for livestock ventilation systems. Final Report to Osborne Industries, and the KS Technology Enterprise Corporation. May 3.
30. Heber, A.J. J.L. Nelssen, D.A. Nichols, and M. Stroik. 1987. Quantitative Analysis of Swine Dust Characteristics and Origin. 1987 Research Investment Report, Nat. Pork Prod. Council. pp 33-35.
31. Heber, A.J. and M. Stroik. 1987. Characteristics of Aerial Dust in Finishing Buildings. KSU Swine Day Report of Progress. pp. 85-88.
32. Heber, A.J. 1983. Performance and Evaluation of Photovoltaic Power. Final Report to Sandia Laboratories, University of Nebraska-Lincoln, June.

## POSTERS

- Heber, A.J., S.-H. Lee, H. Huang, J.-Q. Ni, S. Sharvelle, M. K. Banks, Y. S. Kim. 2004. Testing biofilters for advanced life support. Habitation Conference, Orlanda, Florida, Jan. 5-7.
- Heber, A.J., T.T. Lim, and J.Q. Ni. 2003. Air emissions from a laying hen house. Poultry Day, Purdue University, Oct. 8.
- Heber, A.J. 1998. Agricultural odor control methods. Annual Extension Conf., Purdue Univ., Nov. 17-19.
- Heber, A.J. 1998. Livestock odor control. American Farm Bureau Conf., Charlotte, NC, Jan. 11-13.
- Heber, A.J. and M. Stroik. 1987. Swine house dust. Annual Kansas AES/CES Conference, Oct. 12, 1987. Selected for AES poster session at the Kansas State Capitol, Feb. 2, 1988.

## SOFTWARE (most recent first)

- Heber, A.J. 1999. SETBACK. Odor setback guideline. Interactive on web.
- Heber, A.J. 1998. VENTROOM. Ventilation system design program.
- Li, J. and A.J. Heber. 1993. FANSYS. Fan system design program.
- Heber, A.J. and B. Misra. 1994. AGVENT. Ventilation system design program.
- Heber, A.J. 1994. MGOVEN. Oven design program for conveyor belt ovens. Drafts three views.
- Heber, A.J. 1993. MTOVEN. Oven design program that predicts heat transfer coefficient.

## OTHER PUBLICATIONS (most recent first)

- Heber, A.J. 2003. Air emission measurements at livestock houses: a hide-and-seek challenge to find the numbers. Resource 10(4):7-8.
- Heber, A.J. 1998. Summertime air quality in swine grow-finish buildings. Pork'98. November.



- Heber, A.J. 1998. Setting a setback. *National Hog Farmer* 43(1):62-64.
- Heber, A.J. 1997. Protection distances for sufficient dispersion and dilution of odor from swine buildings. *Swine Day Proceedings*, Purdue University, Aug. 28.
- Heber, A.J. 1995. Mismatched fans throw ventilation out of whack. *Nat. Hog Farmer* 40(4):12-18.
- Heber, A.J. 1993. Improving worker health in hog buildings. *Short Course on Improving Swine Production Efficiency*, Purdue University, pp. 29-42.
- Heber, A.J. 1987. Dust in finishing houses. *KPPC Pig Tales Magazine*. Summer.
- Heber, A.J., T.L. Thompson, and D.D. Schulte. 1984. Managing electrical loads. *Agric.Engg.* 65(6):8-13.
- Heber, A.J. 1984. Electrical load management system for the integrated energy farm: a user's manual. *Agricultural Engineering Department Publication*, University of Nebraska, Lincoln, NE 68583-0726.

#### INVITED PAPERS AND LECTURES (total=45)

1. "Layer Facility Emissions", Texas Commercial Egg Clinic, Bryan, TX, May 13, 2004
2. "Current Progress in US Research and Regulatory Programs on Intensive Livestock Odour and Air Quality", Opening Keynote Presentation, Enviro 04 Conference on Advances in Odour Management: Towards more Livable Communities, Sydney, NSW, AUS, March 29, 2004.
3. "Update Regarding U.S. Air Quality Research and Regulations", Intensive Livestock Odours Workshop, Enviro 04 Conference on Advances in Odour Management: Towards more Livable Communities, Sydney, NSW, AUS, Mar. 29, 2004.
4. "Micromet Methods for Measuring Ammonia and Hydrogen Sulfide Emissions from Livestock Lagoons", Sampling for Odour Measurement Workshop, Enviro 04 Conference on Advances in Odour Management: Towards more Livable Communities, Sydney, NSW, AUS, Mar. 30, 2004.
5. "Measurement, Regulation and Control of Air Emissions from Swine and Poultry Operations", Air Quality Workshop, Pacific Air and Environment, Brisbane, Qld, AUS, Mar. 19, 2004.
6. "Impacts of Emissions from Swine Facilities and Methods and Practices for Mitigation", Pan Pacific Pork Exposition, Brisbane, Qld, AUS, March 18-20, 2004. Presented to Indiana Soybean Association and Indiana Pork Producers Association, March 23, 2004 in absentia.
7. "Air Emission Rates from Laying Houses and the Proposed Nationwide Monitoring Study", Environmental Committee, United Egg Producers, Atlanta, GA, Jan. 26, 2004.
8. "Quality Assured Air Emission Measuring Technologies", Ohio Agricultural Air Quality Research Symposium, Plain City, OH, Jan. 15, 2004.
9. "Field and Laboratory Tests of Air Emission Abatement Strategies", Ohio Agricultural Air Quality Research Symposium, Plain City, OH, Jan. 15, 2004.
10. "Testing Biofilters for Advanced Life Support", NASA ALS Air Quality Workshop, University of Florida, Gainesville, FL, Jan. 8-9, 2004.
11. "Methodology for Measuring Building Emissions", NRCS Air Quality Group, Beltsville, MD, Nov. 18-20, 2003.
12. "Building Emission Measurements Solutions", Key Issue Research Meeting, National Pork Board, Ames, IA, April 7-8, 2003.
13. "Effect of Oil Sprinkling on Odor, Gas and Particulate Matter Emissions from Swine Houses", Technology Review Panel Meeting, Premium Standard Farms, Trenton, MO, Nov. 25-26, 2002.
14. "Studies of Livestock Odor Concentrations and Emissions", Odor Discussion Group Meeting, PBS&J, Beltsville, MD, Oct. 16, 2002.
15. "Managing Odor, Dust and Gas Emissions", GroMaster Seminar on Ventilation, World Pork Exp, Des Moines, IA, June 8, 2002
16. "Nitrogen Loss Measurements in Swine and Poultry Facilities" and "Conference Wrap-Up Comments", ADSA DISCOVER Conference on Nitrogen Losses to the Atmosphere from Livestock and Poultry Operations. Nashville, IN, April 28-May 1, 2002.
17. "Odor Measurement", Symposium on Odour Measurement in Relation to Pig Production at



Danske Slagterier, Copenhagen, Denmark, Mar. 13, 2002.

18. "Agricultural Air Quality and Aerial Pollutant Emissions Research", Danish Institute of Agricultural Sciences, Research Centre Bygholm, Horsens, Denmark, Mar. 11, 2002.
19. "Air Emissions Research at Purdue University", Environmental Committee Meeting, National Pork Board, Ames, IA, Jan. 24, 2002.
20. "Emission Rates from Animal Production Buildings", KSU Air Quality Seminar, Manhattan, KS, Jan. 7-8, 2002.
21. "Measurements of Agricultural Air Quality and Aerial Pollutant Emissions", IMAG, Wageningen, The Netherlands, Dec 7, 2001.
22. "Tests of Pit Additives", Swine Odor and Waste Management Field Day, University of Illinois, Urbana-Champaign, Ill, Aug. 29, 2001.
23. "Dust Measurement Methods", Invited Technical Session, ASAE Annual Meeting, Sacramento, California, July 31-Aug 2, 2001.
24. "Measurement of Air Pollutant Emissions from Livestock Operations" Prairie Swine Centre, Saskatoon, Saskatchewan, Canada, May 31, 2001.
25. "Air Emission Measurements at Livestock Production Facilities", Seminar, Institute for Grassland and Environmental Research, North Wyke, Devon, U.K., Feb 19, 2001.
26. "Measurement of Air Pollution from Livestock Production Facilities", Divisional Seminar, Silsoe Research Institute, Silsoe, Bedford, U.K., Jan 26, 2001
27. "Abatement of Livestock Air and Water Pollution", Workshop. University of Hannover, Hannover, Germany, Sep 28-29, 2000 [<http://agriculture.de/acms1/conf6/ws4prop.htm>]
28. "Measurement of Odor Emissions from Lagoons," Senator Paul Muegge's Odor Reduction Seminar, Oklahoma State Capital, Oklahoma City, OK, June 28, 2000.
29. "Ventilation Demonstration", Livestock Building Operations Workshop, Springfield, IL, Mar 8, 2000.
30. "Electronic Controls Fundamentals and Control Strategies," Livestock Building Operations Workshop, Springfield, IL, Mar. 8, 2000.
31. "Overview of Nationwide Odor Research Efforts," Illinois Waste Management Conference, Urbana-Champaign, IL, Mar. 9. 1999.
32. "Gas and Odor Emission Rates from Large Swine Houses," University of Veterinary Medicine, Vienna, Austria, Nov 24. 1998.
33. "Odor Control Methods for Livestock Producers". Forum on waste and nutrient management at the Annual Conference of American Farm Bureau, Charlotte, NC, Jan 11-13. 1998.
34. "Air Quality and Nuisance Issues". Conference on Livestock and the Environment, Lincoln, Nebraska, Dec. 10. University of Nebraska Cooperative Extension. 1997.
35. "Improving Air Quality In and Around Livestock Facilities." National Conference of Institutional Agribusinesses, Indianapolis, IN, Sept. 28-Oct. 2, 1997.
36. "Odor Protection Setbacks for Swine Buildings." Fifth Meeting of the National Environmental Dialogue on Pork Production. America's Clean Water Foundation, Raleigh, NC, Sept. 10-12. 1997.
37. "Troubleshooting Environmental Problems for Pigs." SAVMA Symp., W. Lafayette, Mar. 15, 1997.
38. "Monitoring Agricultural Respiratory Hazards." National Institute for Farm Safety Summer Conference, Indianapolis, IN, June 21-26, 1997.
39. "How Can We Better Ventilate?" Maple Leaf Growers Meeting, Milford, IN, April 29. 1997.
40. "Ventilation." National Frame Builders Conference, Nashville, TN, Feb 13. 1997.
41. "It's Time to Ventilate." Maple Leaf Growers Meeting, Milford, IN, Jan 11. 1996.
42. "Ventilation applications demonstration." Plyco Regional Meeting, Walkerton, IN, Aug 3. 1996.
43. "Maintaining finish quality with low-VOC wood coatings." 51st Annual Purdue Industrial Waste Conference, May 6-8, 4 pp. 1996.
44. "Improving worker health in hog buildings." Part of IHETS Satellite Short Course series entitled



Improving Swine Production Efficiency. 460 requests for course material from 30 states, Mexico, Canada and Puerto Rico plus 70 requests for video tapes of program from 24 states, Canada, Mexico and Hong Kong. 13 pages. 1994.

45. "Principles of energy conservation in fan ventilated livestock buildings." Energy in Rural America: Profits and Opportunities in Agriculture, Fuels, and Utilities Issues Conf. Des Moines, IA. June 1-3, 12 pp.

## RESEARCH GRANTS, GIFTS, AND PROJECTS (most recent first)

### Purdue University

1. Heber, A.J. 2004. Tests of Layer Feed Additive in Laying House. Rose Acre Farms, \$28,000.
2. Heber, A.J. 2004. Air Quality Tests of Ag-D-Tox in Laying Houses, Ag-D-Tox, \$17,500.
3. Heber, A.J. 2004. Measurement and Control of Air Emissions from Laying Houses in Ohio, Ohio Fresh Eggs, LLC, \$515,350.
4. Heber, A.J. 2004. Test of an Odor Control Additive for Biosolids, and Beef and Dairy Manure. ADM Consolidated Nutrition, \$12,500.
5. Radcliffe, J. S., A.L. Sutton, B.T. Richert, A.J. Heber, G.M. Hill and W.J. Powers. 2003. Baseline and Reduced Gas, Odor and Dust Emission Rates from Swine Wean-Finish Facilities. USDA-NRI, \$194,019/\$460,000.
6. Heber, A.J. 2003. Odor Evaluations for External Clients in 2003. \$7,348.
7. Heber, A.J. 2003. Effect of Essential Oils on Swine Odor. Premium Standard Farms, \$5,930.
8. Heber, A.J. 2003. Donation of EPA Method 5 Sampling Train. Rose Acre Farms, Inc., \$5,200.
9. Heber, A.J. 2003. Test of an Odor Control Additive for Biosolids, and Swine and Dairy Manure. ADM Consolidated Nutrition, \$15,800.
10. Heber, A.J. 2003. Control of Dust, Odor and Gas Emissions from Swine Houses in Missouri by Misting Essential Oils and Water. Premium Standard Farms. \$23,318.
11. Heber, A.J. 2003. Donation of uninterruptible power supply. Baumgartner Environics. \$3,000.
12. Heber, A.J. 2003. FTIR Gas Spectrometer. Purdue Agricultural Research Programs. \$11,414.
13. Heber, A.J. 2003. Control of Dust, Odor and Gas Emissions from Swine Houses in Missouri with Essential Oils. Premium Standard Farms. \$17,772.
14. Heber, A.J. 2003. Travel to Denmark. Purdue Research Foundation, \$1,050.
15. Heber, A.J. 2002. Odor Evaluations for External Clients in 2002. \$10,545.
16. Heber, A.J. 2002. Effect of Biocurtains on Aerial Pollutant Emissions from Swine and Poultry Buildings. National Center for Manure and Animal Waste Management. \$55,530.
17. Jacobson, L.D., A.J. Heber, J.M. Sweeten, Y. Zhang, J. Koziel, G.R. Baughman, D.B. Beasley, S. Hoff and D.S. Bundy. 2002. Improving Measurements of Dust and Ammonia Emissions from Confined Animal Buildings. National Center for Manure and Animal Waste Management. \$7,746/\$65,000.
18. Heber, A.J. 2002. Used Instrumentation. Monsanto EnviroChem. \$32,000 (50% of new cost).
19. Heber, A.J. 2002. Gas Dilution System. Dean of Agriculture. \$8,604.
20. Mitchell, C.A., J.A. Alleman, E. Blatchley, B. Applegate, C.A. Beyl, K. Banks, P. Brown, G. Chiu, C.C. Glass, K.L. Jones, A.J. Heber, B. Joern, M. Ladisch, L. Mauer, P. Pacambaba, J. Pekny, G. C. Sharma, J. Trimble, J. Volenec, L.T. Walker, L.L. Williams, B. Yao, and Y. Yih. 2002. NSCORT Center of Excellence in Advanced Life Support. Minimizing Equivalent Systems Mass for a Regenerative Life Support System by Optimizing Kinetics and Energetics of Major Biotransformations. NASA NSCORT Space Life Science. \$604,569/\$9,600,000.
21. Heber, A.J. 2001. Odor Evaluations for External Clients in 2001. \$30,814.
22. Heber, A.J. 2001. Measurement and Control of Dust, Odor and Gas Emissions from Swine Houses in Missouri. Premium Standard Farms. \$107,169.
23. Heber, A.J. and J.-Q. Ni. 2001. Analysis of Air Quality Data Collected in a High-Rise Swine Farrowing House. Consolidated Nutrition. \$6,289.
24. Jacobson, L.D., A.J. Heber, J.M. Sweeten, Y. Zhang, R. Bottcher and D. Bundy. 2001. Air



- Pollutant Emissions from Confined Animal Buildings. USDA Initiative for Future Agriculture and Food Systems, \$469,699/\$2,150,000.
25. Heber, A.J., H. Xin, R. Gates. 2001. Improving Measurement of Emissions from Poultry Houses. U.S. EPA: Multi-State Consortium on Animal Waste. \$90,125/\$131,200.
  26. Heber, A.J., A. Millmeir. 2001. Measurement and Control of Aerial Pollutant Emissions from Swine Finishing Houses. U.S. EPA: Multi-State Consortium on Animal Waste. \$147,845/\$234,463.
  27. Tischmack, J.K. and A.J. Heber. 2001. Use of Organic Compounds to Control Odors in Biosolids Composting. Purdue Research Foundation. \$15,616.
  28. Sutton, A.L., G.L. Allee, G.M. Hill, B.T. Richert, A.J. Heber, D.D. Jones, K.A. Foster and D.W. Rozeboom. 2001. Diet Modifications to Reduce Nutrient Excretions and Enhance Air Quality in Swine Operations. USDA Initiative for Future Ag and Food Systems, \$80,000/\$1,250,000.
  29. Heber, A.J. 2001. Real-time Dust Concentration Monitor. Purdue Agricultural Alumni Found. \$12,000.
  30. Heber, A.J., J.-Q. Ni, and R. Grant. 2001. Odor, Gas and Dust Emission Factors for Caged-Layers. Indiana Commissioner of Agriculture. \$34,681.
  31. Heber, A.J. 2000. Odor evaluations for external clients in 2000. \$19,022.
  32. Heber, A.J. 2000. Ammonia Produced by Animal Operations. National Center on Animal Waste, University of North Carolina. Subcontract to North Carolina State University, \$2,000.
  33. Heber, A.J. 2000. Site Selection of Animal Operations Using Air Quality Criteria. National Center on Animal Waste, University of North Carolina. Subcontract to University of MN, \$1,000.
  34. Heber, A.J. 2000. Particulate Matter Emissions from Confined Animal Feeding Operations: Management and Control Measures. National Center on Animal Waste, University of North Carolina. Subcontract to Texas A&M University, \$2,000.
  35. Heber, A.J. 2000. Odor Mitigation for Concentrated Animal Feeding Operations: White Paper and Recommendations. National Center on Animal Waste, University of North Carolina. Subcontract to Texas A&M University, \$1,500.
  36. Heber, A.J. 2000. Characterization of Odor Emitting Potential from Swine Barns in Illinois. University of Illinois. \$22,371.
  37. Heber, A.J. 2000. Study for the Effect of Ozonation on Odor, Dust and Gas Concentrations in Swine Barn and Growth Performance in Growing Pigs. University of Illinois. \$2,016.
  38. Heber, A.J., J. Q. Ni, R.H. Grant. 2000. Air Sampling & Measurement Methodology for Confined Animal Housing Systems. U.S. Environmental Protection Agency, \$120,725.
  39. Sutton, A.L., B.T. Richert, A.J. Heber, S. DeCamp, and S. Hankins. 2000. Effect of Ractopamine in Pig Diets on Nutrient Excretion and Odors in Manure. Eli Lilly Research Laboratories. \$35,887.
  40. Heber, A.J. 2000. Collection of Gas Samples for Electronic Nose Analysis. National Soil Tilth Laboratory, Ames, IA. \$1,600.
  41. Heber, A.J. 2000. Visiting Scientist Fellowship. AFRC Underwood Foundation, Silsoe, U.K. \$8,784.
  42. Sutton, A.L., B.T. Richert, and A.J. Heber. 1999. Reduction of Odorous Compounds in Pig Manure through Specific Dietary Manipulation – A Field Study. National Pork Producers Council, \$37,419.
  43. Heber, A.J. 1998-99. Odor Evaluations for External Clients in 1998 and 1999. \$13,650.
  44. Heber, A.J., S.S. Schiffman, and T. Nagle. 1999. Effects of Dust, Sample Handling and other Factors on Quantification of Swine House Odor and Gases. Multi-State Consortium on Waste Management. \$89,000/\$145,900.
  45. Heber, A.J., C.C. Wu, and R.H. Grant. 1999. Atmospheric Dispersion of Pathogens from Ventilation Exhausts. National Pork Producers Council. \$28,496.
  46. Heber, A.J., A.L. Sutton, and D.D. Jones. 1999. Odor Emission from Anaerobic Treatment of Swine Manure. Indiana Commissioner of Agriculture. \$23,166.
  47. Heber, A.J., A.L. Sutton, and J.A. Patterson. 1999. Laboratory Testing of Manure Additives for Odor Control. National Pork Producers Council. \$249,068.



48. Heber, A.J. and A.L. Sutton. 1999. Odor, Ammonia and Hydrogen Sulfide Emission Factors for Grow-Finish Buildings. National Pork Producers Council. \$28,907.
49. Heber, A.J. 1999. Preliminary evaluation of a passive detector to monitor ammonia in livestock buildings. Environmental Test Systems, Inc. \$2,638.
50. Heber, A.J. 1999. Collection of Photobioreactor Feedstock from Swine House Air. Dairillean, Inc. (Subcontract for NSF-SBIR grant). \$35,000.
51. Heber, A.J. 1999. Analysis of air quality data. Monsanto Envirochem. \$400.
52. Heber, A.J. and L. Corson. 1998. Odor Prevention Strategies in Lake County. Indiana Department of Environmental Management. \$24,242.
53. Heber, A.J. 1998. Measurement, Control and Analysis of Swine House Emissions of Dust, Odor and Gases. Multi-State Consortium on Waste Management (second year). \$20,000.
54. Heber, A.J. 1998. Analysis of Ambient Hydrogen Sulfide Readings. B&S Research, \$6,900.
55. Heber, A.J., R. Grant, A.L. Sutton, and D.D. Jones. 1998. Development of a Site-Specific Odor Impact Distance Guideline for Swine Production Systems. National Pork Producers Council (\$29,272) and Purdue Agricultural Research Programs (\$24,000).
56. Heber, A.J. 1998. Development of Olfactometry Laboratory. Agricultural Research Programs and Cooperative Extension Service, Purdue University, \$33,000.
57. Heber, A.J. 1997. Tests of Manure Cover for Odor and Gas Control. ETH International Trading and Recycling, Hamburg, Germany. \$2,250.
58. Sutton, A.L., B.T. Richert, A.J. Heber, D.S. Bundy. 1997-99. Dietary Manipulation to Reduce Odors from Swine Manure. Multi-State Consortium on Waste Management. \$40,000.
59. Heber, A.J., S.J. Hoff, D.S. Bundy, R.W. Bottcher, and K.K. Keener. 1997. Measurement, Control and Analysis of Swine House Emissions of Dust, Odor and Gases. Multi-State Consortium on Waste Management (first year). \$95,200.
60. Heber, A.J. 1997. Travel to Netherlands. Purdue Research Foundation, \$970.
61. Heber, A.J., A.L. Sutton, J.A. Patterson, and D.D. Jones. 1996-97. Field Tests of Alliance. Monsanto Enviro-Chem, \$207,860.
62. Heber, A.J., D. Cassens, and M. Okos. 1996. Effects of Temperature and Humidity on Surface Quality of Low-VOC Wood Coatings, Indiana Department of Environmental Management, \$29,350.
63. Heber, A.J. 1994. Field Test of Bioscrubber for Treating Swine Building Exhaust Air, Indiana Pork Producers Association, \$4,000.
64. Heber, A.J. 1995. Engineering Livestock Housing for Biosecurity. Summer Faculty Grant, Purdue Research Foundation. \$5,000.
65. Heber, A.J. 1995. Gas chromatograph. Purdue Agricultural Alumni Foundation. \$15,000.
66. Heber, A.J. 1995. Study and Evaluation of Turkey House Ventilation Systems. Indiana Turkey Market Development Council. \$6,500.
67. Heber, A.J., R.H. Linton, and N.J. Zimmerman. 1994. The Effect of Processing and Air Flow Parameters on Microbial Aerosol Dispersion in Poultry Processing Plants. American Society of Heating, Refrigeration and Air Conditioning. \$79,987.
68. Heber, A.J. 1994-95. Effects of Management Practices on Air Quality in Swine Farrowing Houses. Indiana Pork Producers Association. \$4,981.
69. Heber, A.J., C.C. Wu, D.D. Jones, J.A. Patterson, A.L. Sutton, Nov. 1993. Effects of Ventilation and Building Hygiene on Aerial Pollutants in Swine Farrowing Rooms. Purdue ARP Research Assistantship Program. \$24,000.
70. Patterson, J.A., A.J. Heber, A.L. Sutton, D.D. Jones. 1993. Development and evaluation of systems for removing NH<sub>3</sub> from exhaust air. Purdue Research Foundation Crossroads Program. \$43,000.
71. Heber, A.J. 1993. Visiting Scientist Fellowship. AFRC Underwood Foundation, Silsoe, U.K. 3100 (\$5,500)
72. Sutton, A.L., J.A. Patterson, D.D. Jones, A.J. Heber. 1993. Odor Control by Biochemical and Microbial Transformations in the Pig and Manure Storage. NPPC. \$98,818.



### Kansas State University

1. Heber, A.J. 1993. Theoretical and Experimental Evaluation of Ventilation Inlet. Kansas Technology Enterprise Corporation (40%) and Osborne Industries (60%). \$21,077.
2. Heber, A.J. 1992. Participation in the Fourth International Livestock Environment Symposium at Coventry, U.K., July 6-9, 1993. KSU Faculty Development Award. \$1400
3. Heber, A.J. and J.P. Harner. 1990. FANSYS: A design program for single and variable speed fans. Kansas Technology Enterprise Corporation (40%) and Osborne Industries (60%). \$20,000
4. Pickrell, J.A., A.J. Heber, J.R. Gillespie, and S. Henry. 1990. Respirable Particle Concentrations in Swine Confinement Operations. National Pork Producers Council. \$20,000
5. Heber, A.J. 1990. Visiting Scientist Fellowship. AFRC Underwood Foundation, Silsoe, U.K.. 3100 (\$5,500)
6. Heber, A.J. 1989. Microprocessor Embedded Controller for Ventilation Fans. Center for Research on Computer Controlled Automation. Kansas State University. \$17,998
7. Morcos, M.M. and A.J. Heber. 1989. Design Optimization of Variable Speed Controllers for Capacitor-Run Induction Motors Running Agricultural Fans. National Food and Energy Council. \$25,600
8. Heber, A.J. 1989. Aerial Reentrainment of Surficial Deposits in Agricultural Structures. KSU Faculty Development Award (50%), Engineering (25%), Ag Engg (25%). \$1200
9. Heber, A.J., M.M. Morcos, and J.P. Harner. 1988. Design Optimization of Variable Speed Fan Systems. Kansas Technology Enterprise Corporation (40%) and Osborne Industries (60%). \$20,000
10. Heber, A.J., M.M. Morcos, and J.P. Harner. 1988. Harmonics Produced by Variable Speed Fan Systems. Kansas Electric Utility Research Program Project KRD 348. \$15,980
11. Heber, A.J., C.K. Spillman, and J.P. Murphy. 1988. Air Quality in Agricultural Buildings. Kansas Agricultural Experiment Station Project Number H 735
12. Heber, A.J. 1988. Effects of Pelletized Fat and Soybean Oil on Aerodynamic Dust Segregation of Swine Feed. Balanced Energy Corporation, Clinton, IA. \$1500
13. Heber, A.J. 1988. Computer Automation and Control of Fan Test Laboratory. Center for Research on Computer Controlled Automation. Kansas State University. \$8,340
14. Heber, A.J. and J.P. Murphy. 1988. Selection of Components for Mechanical Ventilation Systems. Kansas Committee on the Relation of Electricity to Agriculture. \$7,780
15. Heber, A.J., J.P. Murphy, and J. Slocombe. 1987. Variable Speed Control for Direct-Drive Ventilation Fans. Kansas Technology Enterprise Corporation (40%) and Osborne Industries (60%). \$5,000
16. Heber, A.J. and J.P. Murphy. 1987. Effect of Wind on Electric Fan Performance. Kansas Committee on the Relation of Electricity to Agriculture. \$4,920
17. Heber, A.J. 1987. Power Harmonics on Rural Electric Systems. Kansas Committee on the Relation of Electricity to Agriculture. \$2,000
18. Heber, A.J. 1987. University of Minnesota Short Course on Aerosols. KSU Faculty Development Award. \$900
19. Heber, A.J. and J.P. Murphy. 1986. Advancement of Technology for Livestock Ventilation Systems. Kansas Department of Economic Development (40%) and Osborne Industries (60%). \$19,940
20. Heber, A.J., J. Nelssen, and D. Nichols. 1985. Quantitative Analysis of Swine Dust Characteristics and Origin. National Pork Producers Council. Agency Number 367. \$8,954
21. Johnson, G.L. and A.J. Heber. 1985. Measurement of Harmonics on Kansas Utilities. Kansas Electric Utilities Research Program. \$60,318
22. Heber, A.J. and C.K. Spillman. 1985. Environmental Quality and Energy Performance - Livestock Buildings. Kansas Agricultural Experiment Station Project Number R 567

### M.S. GRADUATES SUPERVISED



1. Marcella Stroik, Influence of Environmental Factors on Dust Characteristics in Swine Finishing Buildings, 1987.
2. Steven Cole, Effect of Wind Protection Device on Ventilation for Performance, 1988
3. Junping Li, Electrical Harmonic Content on Kansas Rural Distribution Systems, 1988.
4. Kesuma Suri, Effect of Air Velocity on Agricultural Dust Resuspension from Surfaces, 1991.
5. A.R. El Koubysi, Electrical Harmonics from Variable Speed Fan Systems, 1992
6. Kevin Kaiser, Experimental, Analytical, and Numerical Evaluations of Commercial Ceiling and Wall Ventilation Inlets, 1993
7. Brian Strobel, Effects of Management Practices on Air Quality in Swine Farrowing Houses, 1996
8. Mike Peugh, Ventilation of Poultry Processing Plants, 1996
9. Stacey Firestone, non-thesis, 1996.
10. Ping Shao, Evaluation of Agricultural Odor with Olfactometry and Gas Chromatography, 2001.
11. Pei-Chun Tao, Air Emissions from Naturally Ventilated Swine Buildings, 2002-present
12. Hong Huang, Design of Biofilter Test Lab, 2003-

#### **Ph.D. GRADUATES SUPERVISED**

1. Junping Li, PC-Based Design Program for Variable-Speed Ventilation Fans, 1992
2. Teng Teeh Lim, Pollutant Emissions from Livestock Facilities, 2001
3. Sang-Hun Lee, Biofiltration for Advanced Life Support, 2003-

#### **FULL-TIME RESEARCH ASSOCIATES SUPERVISED**

- Dr. Ravi Duggirala, 1996
- Dr. Kevin Keener, 1996-97
- Dr. Ji-Qin Ni, 1997-present
- Kate Fakhouri, 1999-2001
- Dr. Teng-Teeh Lim, 2001-present
- Dr. Elizabeth Warnemuende, 2001-2002
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- Liang Dong, P.R. China, 1995.
- Dr. Rakesh Trivedi, India, 1996-97.
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1. Development of research plans, 2004.
2. Consultant on greenhouse emissions from agriculture, Florida, 2003.
3. Expert in carbon monoxide poisoning case, 2003.
4. Expert in compost odor nuisance case, IA, 2003.
5. Expert in swine odor nuisance case, 2003.
6. Design of crossflow convection oven, National Gas Institute, Chicago, Illinois, 2003.
7. Expert in swine odor nuisance case, Wyoming, 2003.
8. Expert in dairy calf nursery ventilation case, SD, 2002
9. Expert in ventilation equipment patent infringement case, IN, 2002.
10. Expert in poultry aerial pollutant emission case, Arkansas, 2002.
11. Expert in swine housing equipment and environment case, 2002.



12. Expert in swine and poultry odor nuisance litigation, IA, 2001.
13. Member of oven technology advisory board for major restaurant foods company, Texas, 2001.
14. Consultant to environmental firm on odor emissions from soap plant, OH, 2001.
15. Expert witness in a reverse setback case, Illinois, 2001.
16. Calculation of biogas generation from dairy manure, IN, 2001.
17. Design of conveyor belt oven, National Gas Institute, Illinois, 2001-2003.
18. Evaluation of odor management plan for dairy facilities, Idaho, 2001.
19. Evaluation of air pollution from poultry facilities for U.S. DOJ, OH, 2001-2004.
20. Evaluation of air pollution from swine facilities for U.S. DOJ, MO, 2000-2002.
21. Evaluation of odor control methods for two corn wet milling plants, IN, 2000.
22. Evaluation of waste management and odor control methods at a large dairy farm, MN, 2000.
23. Modeling of stack height effects on dispersion of odor from ethanol plant, MN, 1999.
24. Expert witness in case on pig deaths due to lightning and ventilation failure, IN, 1999.
25. Expert witness in case relating to environmental impact of a large swine facility, SD, 1999.
26. Expert witness in livestock odor nuisance case, MO, 1999.
27. Expert witness regarding proposed odor regulations, CO, 1999.
28. Evaluation of government environmental permit application of swine facility, D.C., 1999.
29. Design of ventilation for poultry buildings, IN, 1998.
30. Expert witness in laying house odor nuisance case, OH, 1998.
31. Modeling stack height effects on dispersion of odor from rendering plant, IN, 1998.
32. Evaluation of aeration for controlling swine lagoon odor, Oklahoma, 1998.
33. Expert witness for case involving fence design, IN, 1998.
34. Evaluation of manure storage cover for controlling odor, Germany, 1997.
35. Expert witness for two broiler odor nuisance cases, KY, 1997.
36. Odor reduction strategies for a hog slaughtering plant, IN, 1996.
37. Troubleshooting swine housing complex for environmental control problems, KS, 1995.
38. Oven redesign and testing, Vermont, 1995.
39. Design of 18"x28" wide conveyor-belt oven, Vermont, 1994.
40. Troubleshooting oven baking problems, Vermont, 1994.
41. Design of remodeling for swine finishing house, MI, 1994.
42. Heat transfer model for device, Pizza Hut, KS, 1994.
43. Design of air return manifold and nozzle plenum for jet impingement oven, Vermont, 1994.
44. Evaluation of fans and air systems for jet-impingement oven, Vermont, 1993.
45. Evaluation of dustiness of corn and feed for ag chemical company, IL, 1993.
46. Testing and system engineering of oven blowers, Vermont, 1993.
47. Design of 18" wide jet-impingement, conveyor-belt oven, Vermont, 1993.
48. Design of 32" wide jet-impingement, conveyor-belt oven, Vermont, 1992 (patent).
49. Ventilation inlet tests for farm equipment company, KS, 1992.
50. Administration of harmonic analyzer service program for utilities, KS, 1989-92.
51. Ventilation fan tests and experiments for farm equipment company, KS, 1987-92.
52. Design of anaerobic lagoon for veterinarian's clinic, KS, 1992.
53. Design of new environmental control system for swine building, KS, 1992.
54. Air system design of 39" wide jet-impingement conveyor-belt pizza oven, Vermont, 1991.
55. Evaluation of dustiness of corn hybrids for ag chemical company, Dupont, 1991.
56. Air system analysis of convection oven for oven company, Vermont, 1991.
57. Ventilation fan motor test for farm equipment company, KS, 1990.
58. Particle size analysis of powder for animal nutrition company, Rhone-Poulenc, 1990.
59. Certification of PURPA guidelines for an on-site cogenerator engine, 1987.
60. Engineering analysis report for a lawsuit involving a farm accident, KS, 1985.

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**PRELIMINARY TEST OF ELECTROSTATIC SPACE CHARGE SYSTEM IN A HIGH-  
RISE LAYER BARN**

**for Ohio Fresh Eggs, Croton, Ohio  
at Barn 2, Site No. 5, 20449 County Rd 245, Mt. Victory, OH 43340**

**by**

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**October 17, 2005**



OCT 19 2005

AIR ENFORCEMENT BRANCH,  
U.S. EPA, REGION 5

## **PRELIMINARY TEST OF ELECTROSTATIC SPACE CHARGE SYSTEM IN A HIGH-RISE LAYER BARN**

**A.J. Heber and T.T. Lim**  
**October 17, 2005**

### **Introduction**

The Electrostatic Space Charge System (ESCS) was tested between September 1 to October 4, 2005 in Layer Barn 2 at Ohio Fresh Eggs' Mt. Victory laying facility (Site #5) to determine its efficacy in controlling emissions of particulate matter (PM) from high-rise layer barns. This is believed to be the first test of an electrostatic PM removal system ever conducted in a large commercial layer barn. Specifically, the objectives of the test were to:

1. Evaluate whether the ESCS has the potential to reduce PM<sub>10</sub> emissions.
2. Study the effect of ESCS voltage on PM removal efficiency.

The test was conducted at the site of the former six-month Particulate Impaction System test that ended on January 31, 2005. The ESCS was installed and operated in Barn 2, while Barn 1 served as the control barn. A system for applying a litter amendment, Liquid Alum, was installed in Barn 2 to control ammonia. The ESCS was initially operated prior to use of the Liquid Alum, followed by an independent test of Alum without the ESCS operating, and was followed by another independent test of the ESCS. By the end of September 2005, both Alum and ESCS were operated simultaneously. The tests were conducted by Dr. Teng Lim, Purdue University, and Mr. Chaoyuan Wang, Ohio State University, with supervision and oversight by Dr. Albert Heber, Purdue University.

The PM<sub>10</sub> measurements were conducted with a real-time monitor located at a winter ventilation fan in each barn. Differences between the ratios of PM<sub>10</sub> emissions at the two barns with and without the ESCS were used to calculate the PM<sub>10</sub> control efficiency of the ESCS.

### **Methods and Procedure**

#### **Description of Laying Barn**

Detailed descriptions of the caged-hen laying barns at Mt. Victory, Ohio (20449 County Road 245, Mt. Victory, Ohio 43340) were provided to EPA in previous reports and in the Quality Assurance Project Plan that was developed for the prior test of the Particulate Impaction Curtain at this facility. A major difference in this test from the prior tests, aside from the type of PM control being tested, was the locations of the manure drying fans in the manure storage pit on the first floor of the barn. The 918-mm dia. auxiliary circulation fans (Model VG36DM3F, J&D Manufacturing, Eau Claire, WI) were repositioned and rearranged to generate air patterns in a 45 degree angle with the length of the barn to minimize exposure of the fans to the sprayed Alum solution. Birds were placed in Barns 1 and 2 in February 2005 and July, 2004, respectively.



### **Description of Electrostatic Space Charge System**

The ESCS (Baumgartner Environics Inc., Olivia, MN) utilizes electrodes to impart electrical charges to particles as they move through the charging field and are attracted to the grounded collection plates. Power supplies with high voltages of 25K–30K VDC and about 2 mA capacity supplied cables with 24 ion discharge needles per foot. Four cables ran along the entire length of the layer barns and were spaced uniformly across the width of the barn (Figure 1). The charged particles are attracted to a ground panel, the floor, the manure, and other grounded surfaces.

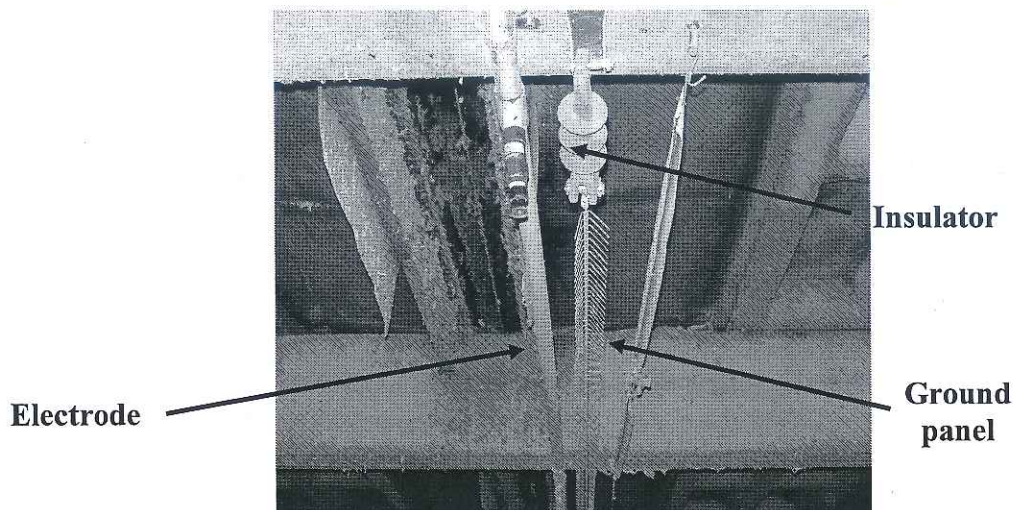


Figure 1. ESCS electrodes and ground panel installed at the ceiling of the manure storage pit.

### **Experimental Design**

Several tests were conducted during this short term evaluation of the ESCS. In Test 1, the ESCS was independently tested from September 1 to 8, 2005. In Test 2, the Alum was independently tested from September 9 to 20, 2005. The ESCS was independently tested again from September 21 to 29, 2005 in Test 3. The Alum spraying system and ESCS have been operating simultaneously since September 29 to October 4, 2005 (Test 4). It is assumed that the alum spraying does not affect the PM concentration since it was sprayed only two seconds per hour. With this assumption, the results of Test 2 can be compared with the results of Tests 3 and 4 to assess the PM reduction potential.

In Test 3, the ESCS cable and electrodes were moved about 15 cm away from the Alum spraying system to avoid damage due to high voltages. Additional adjustments were made to the ESCS on September 26<sup>th</sup> to increase the ESCS voltage. Only the test data from September 10<sup>th</sup> to October 4<sup>th</sup> were used to assess the ESCS in this report.

### **Results**

All of the reported average daily mean (ADM) or hourly mean values consisted of over 70% valid data (complete-data days or complete-data hours) to avoid biasness due to missing data. The average daily mean (ADM) airflow rate and exhaust temperatures of Barns 1 and 2 were 195 and 215 dsm<sup>3</sup>/s, and 24.7 and 24.7°C, respectively. Daily means of selected variables are



reported in Table 1. The ADM ambient PM<sub>10</sub> concentration was 120 µg/dsm<sup>3</sup> and remained relatively stable throughout the entire measurement period, Figure 2.

Table 1. Daily means of temperatures, airflows and emission rates.

Date	Test	Ambient		Barn 1			Barn 2		
		Temp. C	RH %	Temp. C	Airflow dsm <sup>3</sup> /s	Net PM <sub>10</sub> Emission mg/s	Temp. C	Airflow dsm <sup>3</sup> /s	Net PM <sub>10</sub> Emission mg/s
9/10	Alum	21.1	N/A	25.8	219	N/A	25.7	252	N/A
9/11	Alum	20.6	54.7	26.4	227	18.3	26.0	265	36.4
9/12	Alum	21.3	58.3	26.4	235	31.7	26.0	278	58.1
9/13	Alum	21.5	61.5	26.1	242	23.8	26.1	287	46.8
9/14	Alum	21.0	69.0	24.5	257	30.6	25.2	250	57.0
9/15	Alum	19.4	79.5	24.1	219	15.7	24.6	216	36.5
9/16	Alum	14.0	84.7	23.8	139	54.9	23.8	157	34.7
9/17	Alum	13.4	82.2	24.5	212	5.9	24.7	231	24.2
9/18	Alum	17.9	72.1	24.7	N/A	6.9	24.6	242	30.1
9/19	Alum	18.7	71.4	25.1	N/A	23.3	25.0	276	46.1
9/20	A to E	20.5	83.3	N/A	N/A	16.6	N/A	N/A	36.6
9/21	ESCS	19.3	74.7	N/A	N/A	N/A	N/A	N/A	N/A
9/22	ESCS	21.7	73.9	N/A	N/A	N/A	N/A	N/A	N/A
9/23	ESCS	19.1	84.9	23.5	151	N/A	23.7	178	N/A
9/24	ESCS	15.7	86.7	25.1	245	17.0	25.2	267	23.3*
9/25	ESCS	19.1	86.6	24.8	232	16.5	25.0	237	32.3*
9/26	ESCS	18.8	79.8	23.6	117	21.5	22.5	123	37.7*
9/27	ESCS	14.7	70.0	24.2	195	25.0	23.3	216	21.8*
9/28	ESCS	17.3	64.9	22.5	99	32.1	22.5	94	44.5*
9/29	E to both	12.4	61.1	22.2	91	29.0	22.5	85	21.2*
9/30	Both	11.7	58.0	23.4	165	35.9	24.0	171	30.1
10/1	Both	15.6	57.9	25.4	207	30.9	25.8	225	30.9
10/2	Both	19.2	70.4	25.9	221	29.9	26.3	241	29.4
10/3	Both	20.7	70.2	25.7	222	33.1	26.1	239	N/A
10/4	Both	20.2	65.8	24.7	195	19.3	24.7	216	N/A

\*Some daily emission values of B2 contain partial non-ESCS treated data.



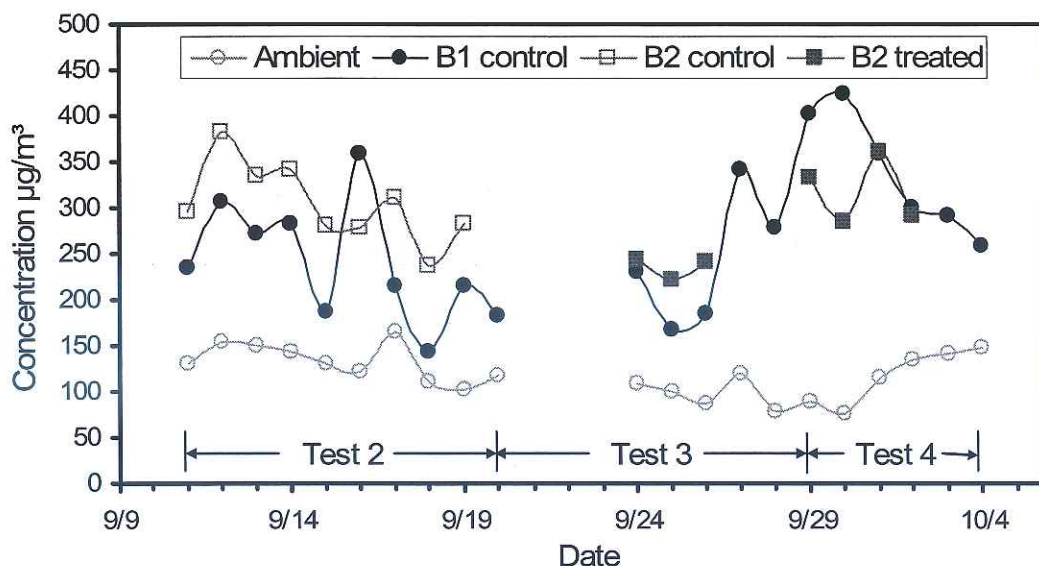


Figure 2. Daily mean PM<sub>10</sub> concentrations of different test periods.

### PM<sub>10</sub> Concentration Reduction using the ESCS

The daily ESCS voltages and concentration and B2/B1 emission ratios are given in Figure 3. During the Alum test (Test 2), the paired ADM PM<sub>10</sub> concentrations for Barns 1 and 2 were 246 and 305 µg/dsm<sup>3</sup>, respectively, and the average concentration ratio of B2/B1 was 1.29 (n=9).

During Test 3 (ESCS at low voltage), the overall paired ADM PM<sub>10</sub> concentrations for Barns 1 and 2 were 267 and 279 µg/dsm<sup>3</sup>, respectively; and the average concentration ratio of B2/B1 was 1.12 (n=4). Based on the barn ratios of PM<sub>10</sub> concentration with and without ESCS operation, the ESCS reduced the PM<sub>10</sub> concentration by 13%.

The operating voltages of the ESCS were increased to above 25 kV for Test 4 (Figure 4). The average barn ratio during Test 4 was 0.89 which was 31% less than Test 2. The reductions appeared to increase with the voltage of the ESCS.



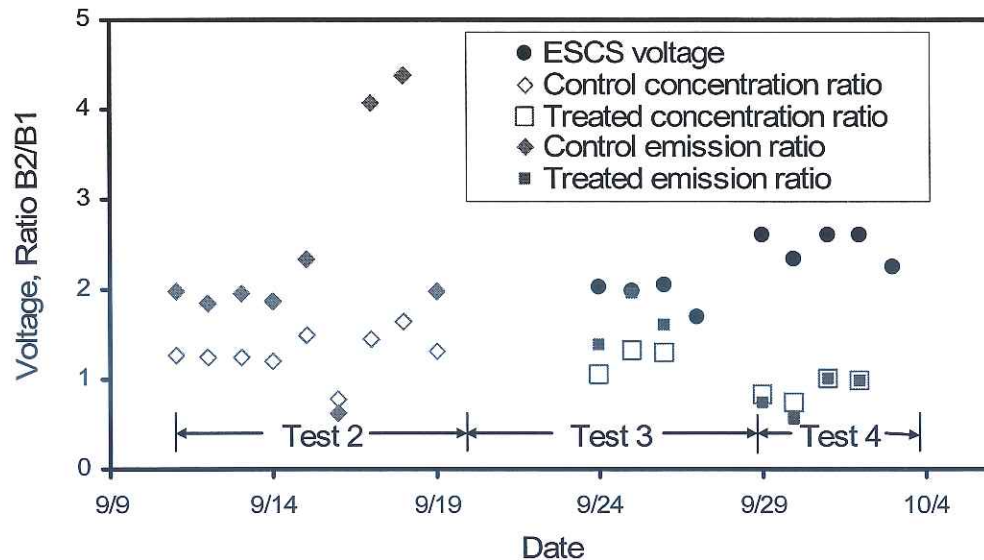


Figure 3. Daily mean ESCS voltages, and PM<sub>10</sub> concentration and emission ratios of Barn2/Barn1.

### PM<sub>10</sub> Emission Reduction using the ESCS

Average daily mean PM<sub>10</sub> emission rates were 22.8 and 40.7 mg/s for Barns 1 and 2 during the Alum spraying period of Test 2, and were 23.5 and 30.1 mg/s during the ESCS test (Test 3). Using the emission ratios of B2/B1 based on daily means, the ESCS reduced the PM<sub>10</sub> emissions by 39%.

The average barn ratio during Test 4 was 0.82, which was 65% less than Test 2. The reductions in emissions increased significantly with the higher voltage setting of the ESCS.

It appears that the ESCS has potential to significantly reduce PM emissions from layer barns. Several things should be considered in interpreting the results of this test:

1. The ESCS was installed in the first floor where the manure is stored whereas the PM is generated by the birds on the second floor.
2. The airflow rates during this preliminary test were higher than normal because of warm temperatures. The residence time of ventilation air in the pit is lower than other times of the year due to high ventilation rates to control the temperature in the barns during hot weather.
3. There was strong evidence of a direct correlation between ESCS voltage and PM reduction. Because of shakedown time required for an unprecedented ESCS installation in a large commercial layer barn like this, the high voltage was not achieved until the very end of the test period.
4. The TSP samples have not yet been analyzed because of the long times required for filter desiccation.



5. Barn 2 had inherently higher PM<sub>10</sub> emissions than Barn 1. This is why the ratios were used to evaluate the effectiveness of the ESCS.

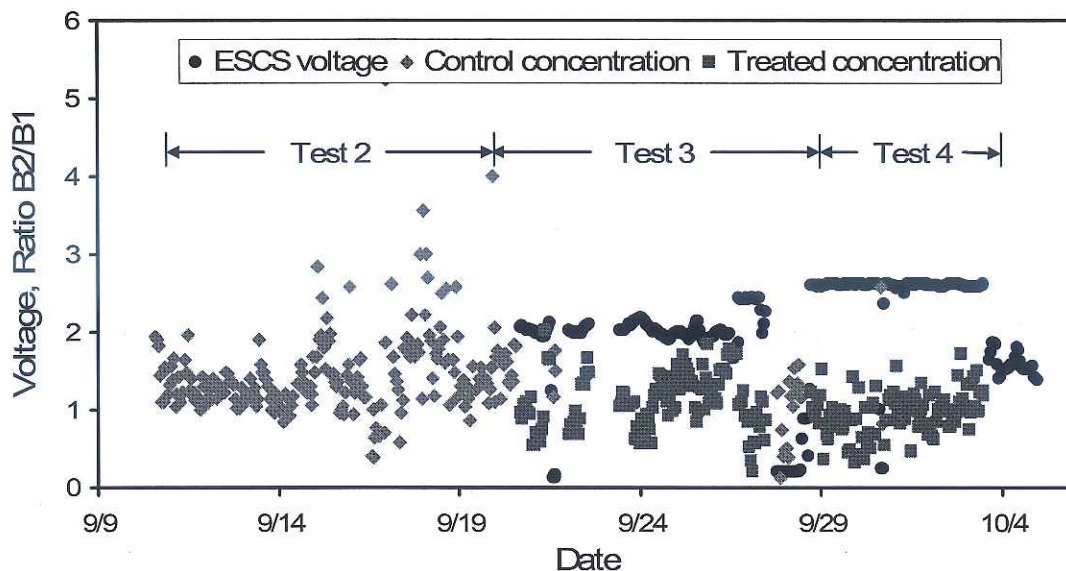


Figure 4. Hourly mean ESCS voltages and PM<sub>10</sub> concentration ratios of B2/B1.

## Conclusions

The following results were obtained at low and high ESCS voltages of around 20 kV and about 25 kV, respectively:

1. The ESCS reduced PM<sub>10</sub> emission by 39% at the low ESCS voltages.
2. The ESCS reduced PM<sub>10</sub> emission by 65% at the high ESCS voltages.